(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 708 542 A2

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.04.1996 Bulletin 1996/17

(51) Int Cl.6: H04J 3/08, H04L 12/437

(21) Application number: 95307185.9

(22) Date of filing: 11.10.1995

(84) Designated Contracting States:
DE FR GB IT NL SE

(30) Priority: 19.10.1994 US 325727

(71) Applicant: AT&T Corp.
New York, NY 10013-2412 (US)

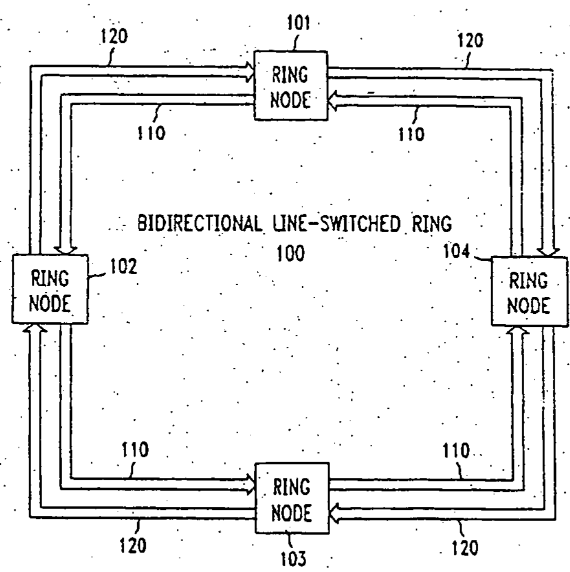
(72) Inventor: Kremer, Wilhelm
Andover, Massachusetts 01810 (US)

(74) Representative:
Buckley, Christopher Simon Thirsk et al
AT&T (UK) LTD.,
AT&T Intellectual Property Division,
5 Mornington Road
Woodford Green, Essex IG8 0TU (GB)

(54) **Generalized deterministic squelching in a ring transmission system**

(57) A method and apparatus for deterministically squelching communications circuits transported by a ring transmission system (100), including communications circuits with combinations of multiple drops, multiple sources and/or multiple broadcasts (in 101-104), is provided, in accordance with the invention, by a) identifying failed ring nodes (101-104) in the ring transmission system including locations of the failed ring nodes; b) identifying communications circuits active in the predetermined ring node; c) squelching a communications circuit active in the predetermined ring node in response to the identifications in steps a) and b) if a first ring node that is downstream from, and adjacent to, the predetermined ring node has failed, and an exit ring node for the communications circuit which is furthest downstream from the predetermined ring node has failed; and d) if no squelching is performed on the communications circuit in accordance with step c), then squelching the communications circuit active in the predetermined ring node if a second ring node that is upstream from, and adjacent to, the predetermined ring node has failed, and an entry ring node for the communications circuit which is furthest upstream from the predetermined ring node has failed.

FIG. 1



Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

This invention relates to ring transmission systems and, more particularly, to generalized deterministic squelching in ring transmission systems.

Background of the Invention

It has become increasingly important to maintain communications connectivity in the presence of transmission system failures. To this end, bidirectional ring transmission systems have been proposed that heal communications circuits in the presence of equipment failure, fiber cuts, and ring node failures. Some bidirectional line-switched ring arrangements employ a deterministic "squelching" method to eliminate or block communications circuits terminated in a failed ring node to avoid undesirable misconnections. The squelching is performed by the switching ring nodes adjacent to the failed ring nodes. Although quite satisfactory for simple bidirectional communications circuits, this known squelching method cannot be extended to cover other types of circuits, for example, unidirectional circuits with various combinations: multiple sources, multiple drops, and/or multiple broadcasts.

Summary of the Invention

A method and apparatus for deterministically squelching communications circuits transported by a ring transmission system, including communications circuits with combinations of multiple drops, multiple sources and/or multiple broadcasts, is provided, in accordance with the invention, by a) identifying failed ring nodes in the ring transmission system including locations of the failed ring nodes; b) identifying communications circuits active in the predetermined ring node; c) squelching a communications circuit active in the predetermined ring node in response to the identifications in steps a) and b) if a first ring node that is downstream from, and adjacent to, said predetermined ring node has failed, and an exit ring node for said communications circuit which is furthest downstream from said predetermined ring node has failed; and d) if no squelching is performed on said communications circuit in accordance with step c), then squelching said communications circuit active in said predetermined ring node if a second ring node that is upstream from, and adjacent to, said predetermined ring node has failed, and an entry ring node for said communications circuit which is furthest upstream from said predetermined ring node has failed.

Brief Description of the Drawing

In the drawing:

FIG. 1 shows, in simplified block diagram form, a bidirectional line-switched ring transmission system including ring nodes incorporating the invention;

FIG. 2 shows, in simplified block diagram form, details of a ring node including an illustrative example of the invention;

FIG. 3 shows, in simplified block diagram form, details of a squelcher used in the ring node of FIG. 2;

FIG. 4 shows, in simplified block diagram form, details of an AIS insert unit employed in the squelcher of FIG. 3;

FIG. 5 is a flow chart illustrating the squelch operation of controller 205 of FIG. 2; and

FIGs. 6-22 illustrate examples of the generalized squelching operations, in accordance with the invention.

Detailed Description

FIG. 1 shows, in simplified form, bidirectional line-switched ring transmission system 100, which for brevity and clarity of exposition is shown as including only ring nodes 101 through 104, each incorporating an illustrative example of the invention. Ring nodes 101 through 104 are interconnected by transmission path 110 in a counterclockwise direction and by transmission path 120 in a clockwise direction. In this example, transmission paths 110 and 120 are comprised of optical fibers and each could be comprised of a single optical fiber or two (2) optical fibers. That is, bidirectional line-switched ring transmission system 100 could be either a two (2) optical fiber or a four (4) optical fiber system. In a two (2) optical fiber system, each of the fibers in transmission paths 110 and 120 includes service bandwidth and protection bandwidth. In a four (4) optical fiber system, each of transmission paths 110 and 120 includes an optical fiber for service bandwidth and a separate optical fiber for protection bandwidth. Such bidirectional line-switched ring transmission systems are known. In this example, transmission of digital signals in the SONET digital signal format is assumed. However, it will be apparent that the invention is equally applicable to other digital signal formats, for example, the CCITT synchronous digital hierarchy (SDH) digital signal formats. In this example, it is assumed that an optical OC-N SONET digital signal format is being utilized for transmission over transmission paths 110 and 120. The SONET digital signal formats are described in a Technical Advisory entitled "Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria", TA-NWT-000253, Bell Communications Research, Issue 6, September 1990.

It is noted that requests and acknowledgments for protection switch action are transmitted in an automatic protection switch ("APS") channel in the SONET overhead accompanying the protection bandwidth on each of transmission paths 110 and 120. The APS channel,

in the SONET format, comprises the Kl and K2 bytes in the SONET overhead of the protection bandwidth. The K1 byte indicates a request of a communications circuit for switch action. The first four (4) bits of the K1 byte indicate the switch request priority and the last four (4) bits indicate the ring node identification (ID). The K2 byte indicates an acknowledgment of the requested protection switch action. The first four (4) bits of the K2 byte indicate the ring node ID and the last 4 bits indicate the action taken. For purposes of this description, a "communications circuit" is considered to be a SONET STS-3 digital signal having its entry and exit points on the ring.

Each of ring nodes 101 through 104 comprises an add-drop multiplexer ("ADM"). Such add-drop multiplexer arrangements are known. For generic requirements of a SONET based ADM see the Technical Reference entitled "SONET ADD-DROP Multiplex Equipment (SONET ADM) GENERIC CRITERIA", TR-TSY-000496, Issue 2, September 1989, Supplement 1, September 1991, Bell Communications Research. In this example, the ADM operates in a transmission sense to pass signals through the ring node, to add signals at the ring node, to drop signals at the ring node, to bridge signals during a protection switch and to loop-back-switch signals during a protection switch at the ring node.

FIG. 2 shows, in simplified block diagram form, details of ring nodes 101 through 104, including an embodiment of the invention. In this example, a west (W)-to-east (E) digital signal transmission direction is assumed in the service bandwidth and the protection bandwidth on transmission path 110. It will be apparent that operation of the ring node and the ADM therein would be similar for an east (E) - to - west (W) digital signal transmission direction in the service bandwidth and the protection bandwidth on transmission path 120. Specifically, shown is transmission path 110 entering the ring node and supplying an OC-N SONET optical signal to receiver 201, where N could be, for example, 12 or 48. Receiver 201 includes an optical/electrical (O/E) interface 202 and a demultiplexer (DEMUX) 203, which yields at least one (1) STS-M SONET digital signal. Such O/E interfaces and demultiplexers are known. In this example, M is assumed to be three (3) and N is greater than M. The STS-M signal output from DEMUX 203 is supplied to squelcher (S) 204 which under control of controller 205 controllably squelches, i.e., blocks particular incoming communications circuits by inserting an alarm indication signal (AIS), as described below. Details of squelcher (S) 204 are shown in FIGs. 3 and 4 and its operation is described below. Thereafter, the STS-M signal, squelched or otherwise, is supplied to broadcast element 206. A broadcast element replicates the STS-M signal supplied to it and supplies the replicated signals as a plurality of individual outputs. Such broadcast elements are known. Broadcast element 206 generates three identical STS-M signals and supplies one STS-M signal to an input of 3:1 selector 207, a second STS-M signal to an input of 2:1 selector 208 and a third STS-M signal to an input of 3:1 selector 209. An STS-M signal output from 3:1 selector 207 is supplied to squelcher (S) 210, which is identical to squelcher (S) 204. Squelcher (S) 210 is employed, under control of controller 205, to squelch particular outgoing communications circuits. The STS-M signal output from squelcher (S) 210 is supplied to transmitter 211 and, therein, to multiplexer (MUX) 212. The output of MUX 212 is an electrical OC-N digital signal, which is interfaced to transmission path 110 via electrical/optical (E/O) interface 213. Such multiplexers (MUXs) and electrical/optical (E/O) interfaces are well known.

Similarly, in the east (E) - to - west (W) direction an OC-N optical signal is supplied via transmission path 120 to receiver 214 and, therein, to optical/electrical (O/E) interface 215. In turn, demultiplexer (DEMUX) 216 yields a STS-M signal which is supplied via squelcher (S) 217 to broadcast element 218. Broadcast element 218 replicates the STS-M signal into a plurality of identical STS-M signals, in this example, three (3). One STS-M signal is supplied to an input of 3:1 selector 207, a second STS-M signal is supplied to an input of 2:1 selector 208 and a third STS-M signal is supplied to an input of 3:1 selector 209. An output from 3:1 selector 209 is supplied via squelcher (S) 219 to transmitter 220. In transmitter 220, multiplexer (MUX) 221 multiplexes the STS-M into an electrical OC-N and, then, electrical/optical (E/O) interface 222 supplies the optical OC-N signal to transmission path 120.

Controller 205 operates to effect the deterministic squelching of communications circuits, in accordance with the principles of the invention. Controller 205 communicates with receivers 201 and 214 and transmitters 211 and 220 via bus 223 and with interface 224 via bus 227. Specifically, in this illustrative example, controller 205 monitors the incoming digital signals to determine loss-of-signal, SONET format K bytes and the like. Additionally, controller 205 causes the insertion of appropriate K byte messages for protection switching purposes, examples of which are described below. To realize the desired deterministic squelching of the communications circuits, controller 205 may be advantageously provisioned via bus 228 with the identities ("IDs") of all the active communications circuits in the ring node. These include those communications circuits passing through the ring node, as well as those communications circuits being added and/or dropped at the ring node. The identities of all the ring nodes in bidirectional line-switched ring 100 may also be provisioned to controller 205. However, in-band signaling may also be used to supply ring nodes 101 through 104 with the identities of all the ring nodes in bidirectional line-switched ring 100 and the identities of communications circuits active in the ring node. In this scheme, control signals are embedded in the data stream itself. Alternatively, such identification could also be made using a central controller at some remote location to the ring, and the re-

sults forwarded to each ring node 101 through 104. The squelching of communications circuits under control of controller 205 to effect the invention is described below.

Interface 224 is employed to interface to a particular duplex link 225 and could include any desired arrangement. For example, interface 224 could include a DS3 digital signal interface to a DSX, a STS-IE (electrical) SONET digital signal interfacing to a DSX, an optical extension interface to an OC-N SONET optical signal or the like. Such interface arrangements are known. Specifically, a signal (R) to be dropped at the ring node is supplied to interface 224 via 2:1 selector 208, under control of controller 205, from either broadcast element 206 or broadcast element 218. In turn, interface 224 supplies the appropriate signal to duplex link 225. A signal (T) to be added at the ring node is supplied from duplex link 225 to interface 224 where it is converted to the STS-M digital signal format, if necessary. The STS-M digital signal is then supplied to broadcast element 226 where it is replicated. The replicated STS-M digital signals are supplied by broadcast element 226 to an input of 3:1 selector 207 and an input of 3:1 selector 209. In this example, 3:1 selectors 207 and 209, under control of controller 205, select the signal being added for transmission in the service bandwidth or the protection bandwidth on either transmission path 110 or transmission path 120.

It should be noted that. in this example, the normal transmission path for a digital signal being added at the ring node would be in the service bandwidth on transmission path 110 and transmission path 120, for example, towards the west (W). If there were to be a protection switch, the signal (T) being added from interface 224 would be bridged via broadcast element 226 and chosen by 3:1 selector 207, under control of controller 205. to the protection bandwidth on transmission path 110. Similarly, if there were to be a loop-back protection switch and the ring node was adjacent to the failure, the signal (R) to be dropped at the ring node would be received in the protection bandwidth on transmission path 120 and would be switched from broadcast element 218 via 2:1 selector 208 to interface 224. It is noted that "failure" or "ring node failure' as used herein is intended to include node equipment failure and "node isolation failure" caused by optical fiber cuts, cable cuts or the like. A node isolation failure is a failure where a group of one or more ring nodes appear to be failed since they are unreachable by other ring nodes in the ring transmission system because of other failed ring nodes or by fiber and/or cable cuts. If the transmission path for the signal (R) is the protection bandwidth. the signal (R) to be dropped would be switched in a ring node adjacent the failure from the protection bandwidth on transmission path 120 to the service bandwidth on transmission path 110 and received at the ring node in the usual fashion. Then. the signal (R) being dropped from transmission path 110 is supplied via broadcast element 206 and 2:1 selector 208 to interface 224.

As indicated above. controller 205 monitors the status of interface 224 and the digital signal supplied thereto via bus 227. Specifically, controller 205 monitors interface 224 for loss-of-signal. coding violations and the like, i.e., a signal failure condition. Under control of controller 205, digital signals may be passed through, added at. dropped at, bridged at or loop-back-switched at the ring node. A loop-back-switch of an STS-M digital signal incoming in the service bandwidth on transmission path 110 is effected by controller 205 causing 3:1 selector 209 to select the STS-M digital signal from broadcast element 206 and supplying it via squelcher (S) 219 to transmitter 220. In turn, transmitter 220 supplies an OC-N optical signal to the protection bandwidth on transmission path 120. It will be apparent that in the loop-back-switch operation, if the signal is incoming in a service bandwidth on transmission path 110, it will be loop-back-switched to the protection bandwidth on transmission path 120 and vice versa. If the signal is incoming in protection bandwidth on transmission path 110. it will be loop-back-switched to the service bandwidth on transmission path 120 and vice versa. A signal to be added at the ring node is supplied from interface 224, replicated via broadcast element 226 and selected either by 3:1 selector 207 or 3:1 selector 209, under control of controller 205, to be added on transmission path 110 or transmission path 120, respectively. A digital signal to be dropped at the ring node is selected by 2:1 selector 208, under control of controller 205, either from broadcast element 206 (transmission path 110) or broadcast element 218 (transmission path 120). The pass-through and loop-back-switch functions for a signal incoming on transmission path 120 is identical to that for an incoming signal on transmission path 110.

Possible communications circuit misconnections are avoided in bidirectional line-switched ring 100, in accordance with the invention, by deterministically squelching particular communications circuits active in a particular ring node using a generalized deterministic squelching method which is described in detail below. To this end, each ring node in bidirectional line-switched ring transmission system 100 is typically equipped to effect the desired squelching via squelchers (S) 204, 210, 217 and 219, under control of controller 205. In this example. both incoming and outgoing communications circuits are squelched, however, it may only be necessary to squelch outgoing communications circuits.

FIG. 3 shows, in simplified block diagram form, details of an exemplary squelcher (S) unit. Specifically, the STS-M digital signal is supplied to demultiplexer (DEMUX) 301 where it is demultiplexed into its constituent M STS-I digital signals 302-1 through 302-M. The M STS-1 digital signals are supplied on a one-to-one basis to AIS insert units 303-1 through 303-M. AIS insert units 303-1 through 303-M, under control of controller 205, insert the AIS in the STS-1 digital signals included in the communications circuits, i.e., STS-M digital signals, to be squelched. Details of AIS insert units 303 are shown

in FIG. 4 and described below. Thereafter, the M STS-I digital signals are multiplexed in multiplexer (MUX) 304 to yield the desired STS-M digital signal. The details of multiplex schemes for the STS-M digital signal are described in the technical advisory TA-NWT-000253, noted above.

FIG. 4 shows, in simplified block diagram form, details of AIS insert units 303. Specifically, shown is a STS-1 digital signal being supplied to AIS generator 401 and to one input of 2:1 selector 402. AIS generator 401 operates to insert AIS in the STS-1 digital signal. As indicated in the technical advisory TA-NWT-000253, the STS path AIS is an all ones (I's) signal in the STS-1 overhead bytes H1, H2 and H3 and the bytes of the entire STS SPE (synchronous payload envelope). Selector 402 selects as an output, under control of controller 205, either the incoming STS-I digital signal or the STS-1 digital signal with AIS inserted from AIS generator 401.

Deterministic squelching is provided, in accordance with the invention, by a method where, despite ring node failures, a communications circuit is delivered to as many drops as possible so long as there is at least one source that has not failed. It will be shown below that a generalized squelching method can be derived from two rules that have been developed, in accordance with the invention, for basic unidirectional circuits. For both rules, it is assumed that the particular ring node of interest (i.e., that ring node used as the loop back switching ring node to heal the ring), is adjacent to a failed ring node. These rules are:

1) Assume, with respect to the switching ring node, that one or more failed ring nodes are in the direction of a unidirectional communications circuit (i.e., the failed ring nodes including the failed adjacent ring node are downstream from the switching ring node). Squelch the communications circuit, in the direction of the communications circuit, if and only if the ring node failure scenario includes the last exit ring node for the communications circuit. (The last exit ring node is the exit ring node that is furthest downstream from the switching ring node); and,

2) Assume, with respect to the switching ring node, that the failure is in the opposite direction from the direction of the unidirectional communications circuit (i.e.. the failed ring nodes including the failed adjacent ring node are upstream from the switching ring node). Squelch the communications circuit, in the direction of the communications circuit, if and only if the ring node failure scenario includes the first entry ring node for the communications circuit. (The first entry ring node is the entry ring node that is furthest upstream from the switching ring node).

Those skilled in the art will appreciate that rules 1) and 2) may be applied to unidirectional circuits having one or more sources and one or more drops. Accordingly, communications circuits falling under these rules include, for example, unidirectional communications circuits having a single source and a single drop, and communications circuits having various combinations of one or more sources, one or more drops, and/or multiple broadcasts. Also, it will be apparent that the combinations of rules 1) and 2) achieve the results provided by the known method for bidirectional squelching of simple bidirectional communications circuit at a given ring node when the communications circuit is terminated at a failed ring node. For the ring interworking scheme described in ANSI T1X1.5/91-043, the bidirectional interworking circuit can be viewed as a multiply dropped circuit with two drops (drop and continue) which is multiply sourced with two sources in the other direction. Thus, the combination of rules 1) and 2) also achieve the results provided by the known squelching method for ring interworking. However, the squelching method of the present invention is not limited to simple bidirectional communications circuits or ring interworking schemes since it generalized to govern deterministic squelching for other circuit types as well. Thus, practicing the squelching method of the present invention is advantageous since a greater variety of communications services can now be provided for in the context of conventional ring transmission system architecture design.

FIG. 5 is a flow chart illustrating the operation of controller 205 in controlling the ring nodes in order to effect the deterministic squelching of communications circuits in the presence of ring node failures, in accordance with the rules discussed above. The process is entered via step 501. Then, operational block 502 causes the K bytes of an incoming OC-N signal to be observed and processes the ring node IDs therein. Then, conditional branch point 503 tests to determine if the processed ring node IDs indicate that one or more ring nodes have failed. Again, a ring node failure is defined as to include ring node equipment failure and node isolation failure caused by fiber cuts and the like. Specific examples of failure conditions are discussed below. Thus, if the processed ring node IDs indicate no ring node failure, the failure is other than a ring node and operational block 513 causes the usual bidirectional ring bridging and switching to be effected as appropriate. Thereafter, the process is ended via step 514. If the processed ring node IDs indicate one or more ring node failures, operational block 506 causes the failed ring node IDs to be identified. Then, control is passed to operational block 507 which allows the identification of communications circuits potentially affected by the one or more failure. A communications circuit is potentially affected by the failure if it has an entry and/or exit (i.e.. an "A" and/or "Z" termination) in the one or more failed ring nodes. However, as discussed above in accordance with the invention, squelching does not have to be performed simply because a communications circuits has a termi-

nation in a failed ring node. Thus, the process continues by going to conditional branching point 508. If the ring node failure scenario does not include a ring node adjacent to the switching ring node. then no squelching is performed, and the usual bridging and switching may occur as appropriate in operational block 513. If the failure scenario includes an adjacent ring node, then control is passed to conditional branching point 509. If the failed adjacent ring node is upstream from the switching ring node then control is passed to operational block 513. If an entry ring node for a communications circuit which is furthest upstream from the switching ring node has failed, then control is passed to operational block 512 where the communications circuit is squelched. If the furthest upstream entry ring node has not failed then control is passed to conditional branching point 511. Referring back to conditional branching point 509, if the failed adjacent ring node is downstream from the switching ring node. then control is passed to conditional branching point 511. If an exit ring node for a communications circuit which furthest downstream from the switching ring node has failed. then control is passed to operational block 512 where the communications circuit is squelched. If the furthest downstream exit ring node has not failed then the usual bridging and switching may occur as appropriate in operational block 513. Thereafter, the process is ended in step 505. In block 506 in FIG. 5, the steps of identifying failed ring nodes and identifying affected active communications circuits may be performed, for example, by using a ring "maps," or look-up tables, which are stored in each ring node in the system, in combination with line-switch request messages generated by the ring nodes. The ring maps could include, for example, information regarding the order in which ring nodes appear on the ring and ring node addresses at which each communications circuit enters and exits the ring. As discussed above, a given communications circuits may have multiple sources and multiple drops which implies multiple entry and exit ring node addresses. STS time slot information may also be included in the maps where appropriate. One example of the use of ring maps and line-switch request messages to identify failed ring nodes follows. Suppose a segment of a ring consisting of three ring nodes A. B. and C is observed. where B has failed. In a typical scenario, both A and C will send line-switch request messages in the APS channel KI byte destined for B. When A sees the request from C, fails to receive a signal from B (i.e., A detects a loss-of-signal). and sees that B is between A and C (using the ring map), it can determine that B is isolated from the ring. A and C will then use their respective ring maps, and apply rules 1) and 2) above, to determine which communications circuits are affected by the failure of B, and squelch those affected circuits by inserting AIS, as described above, to thereby avoid misconnections. A second example of the use of ring maps, loss-of-signal information. and line-switch request messages to identify failed ring nodes is given in my co-pending application serial number 07/855,782, the disclosure of which is incorporated by reference herein. In this second example, rules 1) and 2), are not applied to determine whether a particular communications circuit is affected by the ring node failures. Instead, communications circuits are simply squelched if they have a termination in a failed adjacent ring node. However, those skilled in the art will appreciate that the described signaling is readily applicable to the present invention as an example of how the identification step in operational block 506 in FIG. 5 may be performed.

FIGs. 6-22 illustrate examples of the operations of the generalized squelching rules discussed above.

FIGs. 6-9 show a unidirectional circuit having a single entry ring node and a single exit ring node. In FIGs. 6 and 7, the downstream ring node adjacent to the switching ring node has failed. In FIG. 6, no squelching is performed because, in accordance with rule 1) above, the single exit ring node, which by definition is the exit ring node furthest downstream from the switching ring node, has not failed. In FIG. 7, squelching is performed because the exit ring node has failed. In FIGs. 8 and 9, the upstream ring node adjacent to the switching ring node has failed. In FIG. 8, no squelching is performed because. in accordance with rule 2) above, the single entry ring node, which by definition is the entry ring node furthest upstream from the switching node, has not failed. In FIG. 9, squelching is performed because the entry ring node has failed. As noted above, the combination of rules 1) and 2) give the known method for squelching simple bidirectional communications circuits, which is illustrated in FIGs. 10 and 11.

FIG. 12 shows a multiply dropped unidirectional circuit. As discussed above, the generalized squelching method. in accordance with the invention, provides for delivery to as many drops as possible despite ring node failures. Referring now to FIGs. 13 and 14, the downstream ring node adjacent to the switching ring node has failed. In FIG. 13, no squelching is performed because. in accordance with rule 1) above, the exit ring node furthest downstream from the switching ring node has not failed. In FIG. 14. squelching is performed because the exit ring node furthest downstream from the switching ring node has failed. FIGs. 15 and 16 show that the upstream ring node adjacent to the switching ring node has failed. In FIG. 15, no squelching is performed because. in accordance with rule 2) above. the entry ring node furthest upstream from the switching ring node has not failed. In FIG. 16. squelching is performed because the entry ring node furthest upstream from the switching ring node has failed.

FIG. 17 shows a multiply sourced unidirectional circuit. As above, the intent of the squelching method. in accordance with the invention, is to deliver the communications circuit so long as there is at least one source that has not failed. Referring now to FIGs. 18 and 19. the downstream ring node adjacent to the switching ring node has failed. In FIG. 18, squelching is not performed

because, in accordance with rule 1) above, the exit ring node furthest downstream from the switching ring node has not failed. In FIG. 19, squelching is performed because the exit ring node furthest downstream from the switching ring node has failed. FIGs. 20 and 21 show that the upstream ring node adjacent to the switching ring node has failed. In FIG. 20, no squelching is performed because, in accordance with rule 2) above, the entry ring node furthest upstream from the switching ring node has not failed. In FIG. 21, squelching is performed because the entry ring node furthest upstream from the switching ring node has failed.

FIG. 22 shows another example of the generalized squelching method, in accordance with the invention. FIG. 22 shows two simple unidirectional circuits. Assume that both use the same tributary timeslot. Using rules 1) and 2) above, if ring node B fails, both circuits are squelched. Now suppose that FIG. 22 represents a variation of ring interworking where two unidirectional circuits occupy the same timeslot. Suppose, therefore, that it is desirable to permit a secondary connection during the failure of ring node B (as is the case in ring interworking). Now squelching is only dependent on A and C and not B. If ring node B fails. the circuits are not squelched and a secondary connection is permitted from A to C. It is evident from the two examples illustrated by FIG. 22 that the service intent is needed in order to determine how to squelch. Merely knowing the entry and exit ring nodes is not sufficient in special cases such as these.

The above-described arrangements are. of course, merely illustrative of the application of the principles of the invention. Other arrangements may be devised by those skilled in the art without departing from the spirit or scope of the invention. For example, other arrangements may equally be employed to realize the desired squelching of the communications circuits. The squelching may be realized, for example, by simply not bridging or loop-back-switching the communications circuits.

Claims

1. A method for use with a predetermined ring node of a plurality of ring nodes in a ring transmission system, said ring transmission system transporting communications circuits having at least one entry ring node and at least one exit ring node, the method comprising the steps of:

   a) identifying failed ring nodes in said ring transmission system including locations of said failed ring nodes;
   b) identifying communications circuits active in said predetermined ring node;
   c) squelching a communications circuit active in said predetermined ring node in response to said identifications in steps a) and b) if

      a first ring node that is downstream from, and adjacent to, said predetermined ring node has failed, and
      an exit ring node for said communications circuit which is furthest downstream from said predetermined ring node has failed; and

   d) if no squelching is performed on said communications circuit in accordance with step c), then squelching said communications circuit active in said predetermined ring node if

      a second ring node that is upstream from, and adjacent to, said predetermined ring node has failed, and
      an entry ring node for said communications circuit which is furthest upstream from said predetermined ring node has failed.

2. The method as claimed in claim 1 wherein said communications circuit active in said predetermined ring node has a plurality of sources.

3. The method as claimed in claim 1 wherein said communications circuit active in said predetermined ring node has a plurality of drops.

4. The method as claimed in claim 1 wherein said communications circuit active in said predetermined ring node has a plurality of sources and a plurality of drops.

5. The method as claimed in claim 1 wherein said active communications circuit includes communications circuits being added at said predetermined ring node. communications circuits being dropped at said predetermined ring node, and communications circuits passing through said predetermined ring node.

6. The method as claimed in claim 1 wherein said ring transmission system is a bidirectional ring transmission system.

7. The method as claimed in claim 1 wherein said step of identifying failed ring nodes includes monitoring signals incoming to said predetermined ring node.

8. The method as claimed in claim 7 wherein said step of monitoring includes detecting a signal failure condition incoming to said predetermined ring node on either a first or a second transmission path, said first transmission path coupling said plurality of ring nodes and transporting communications circuits around said ring transmission system in a first direction: said second transmission path coupling said plurality of ring nodes and transporting communica-

tions circuits around said ring transmission system in a second direction opposite said first direction.

9. The method as claimed in claim 8 wherein said step of monitoring includes detecting at least one switch request message incoming to said predetermined ring node on either said first or said second transmission path.

10. The method as claimed in claim 9 further including storing identities of ring nodes in said ring transmission system in said predetermined ring node.

11. The method as claimed in claim 9 wherein said step of identifying failed ring nodes is responsive to said stored identities of ring nodes in said ring transmission system and said detected at least one switch request message for identifying failed ring nodes from said stored identities.

12. The method as claimed in claim 9 wherein said at least one switch request message is transported in an automatic protection switch channel in said protection bandwidth of both said first and said second transmission paths.

13. The method as claimed in claim 12 wherein said automatic protection switch channel comprises at least a Kl byte in overhead of said protection bandwidth.

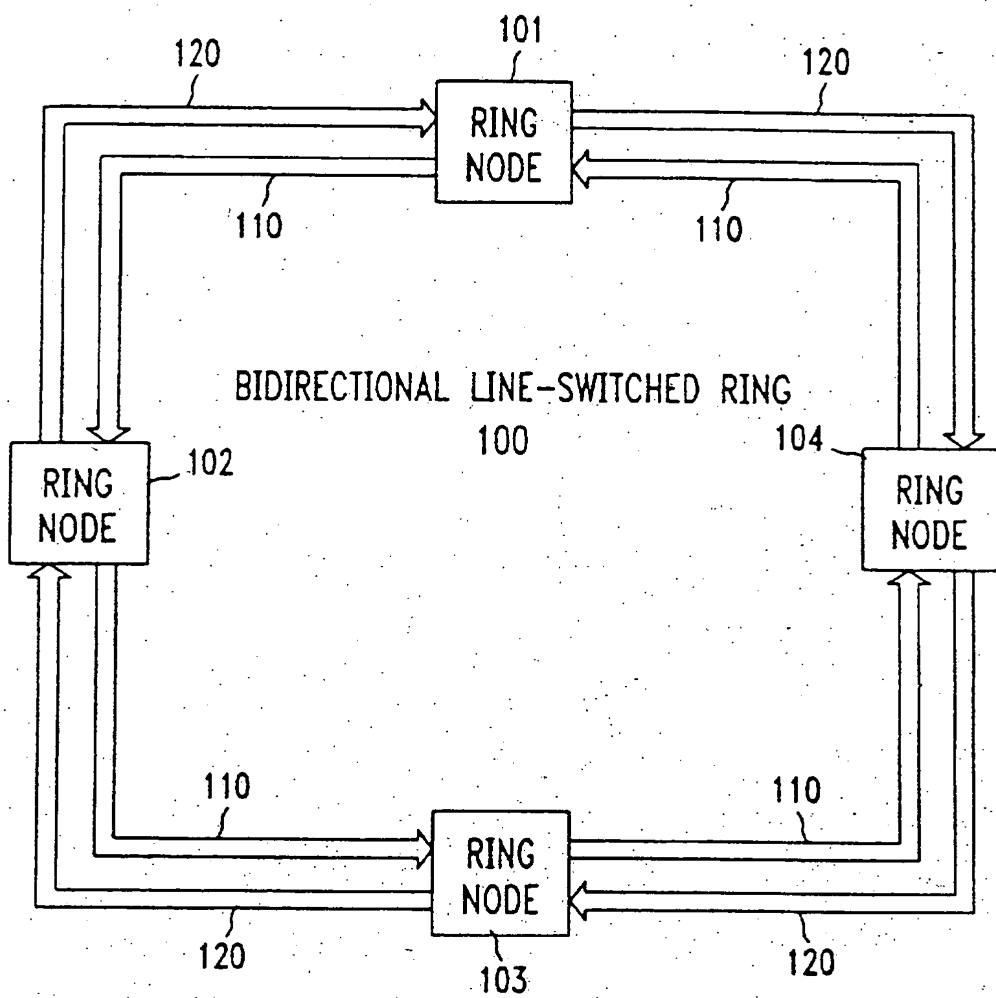
14. The method as claimed in claim 1 wherein said steps of squelching include blocking transmission of said communications circuit to be squelched.

15. The method as claimed in claim 1 wherein said steps of squelching include generating an alarm indication signal and inserting said alarm indication signal in prescribed byte positions in said communications circuits to be squelched.

16. The method as claimed in claim l wherein said step of identifying failed ring nodes includes receiving ring node failure information from a central controller.

17. The method as claimed in claim 1 wherein said step of identifying failed ring nodes includes receiving ring node failure information via in-band signaling.

FIG. 1


101
120
120
RING
NODE
110
110
BIDIRECTIONAL LINE-SWITCHED RING
100
104
RING
NODE
102
RING
NODE
110
110
RING
NODE
120
120
103

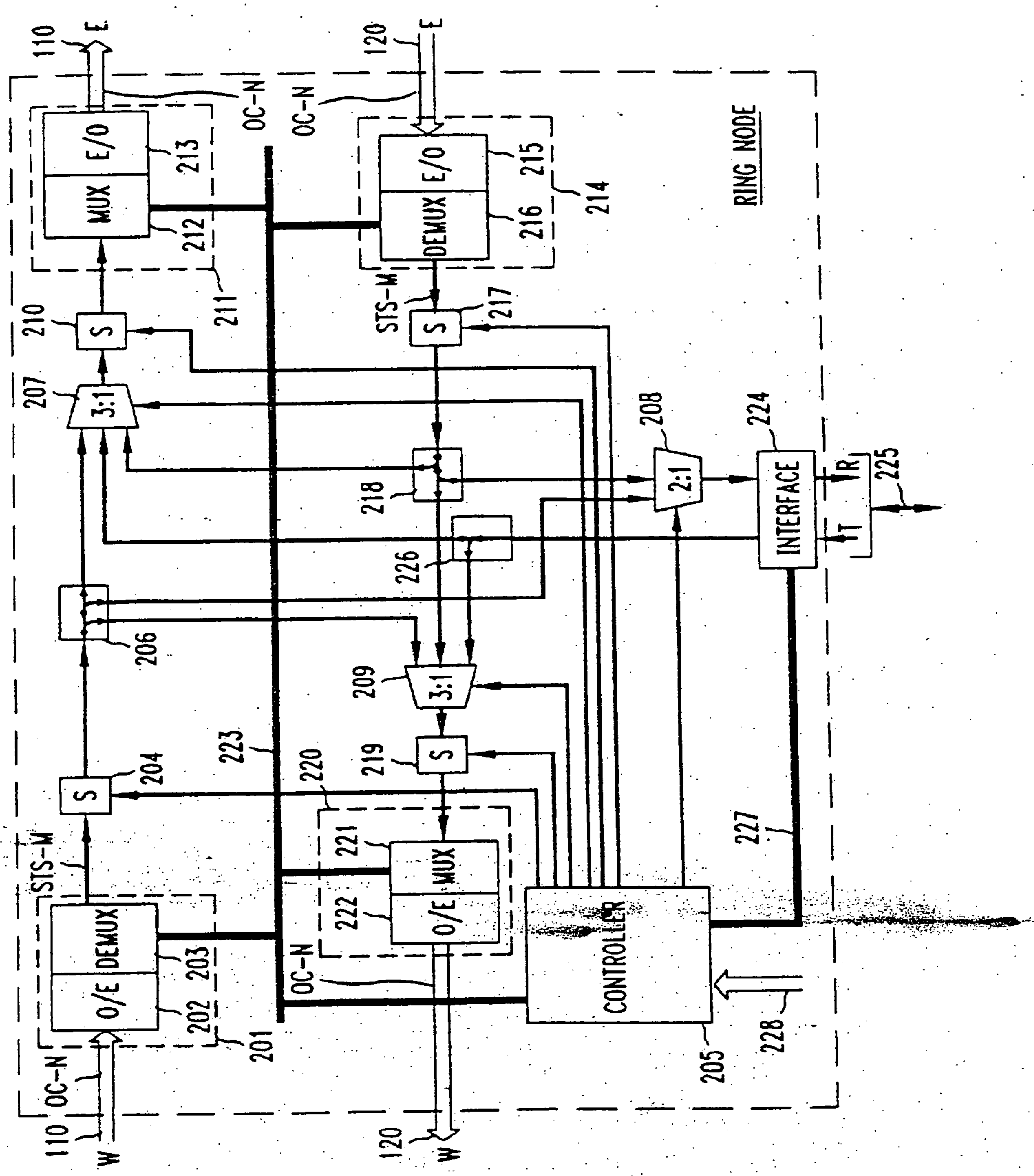

RING NODE
OC-N
STS-M
E/O
MUX
DEMUX
O/E
S
3:1
2:1
INTERFACE
CONTROLLER
R
T
E
W
110
120
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228

FIG. 2

FIG. 3

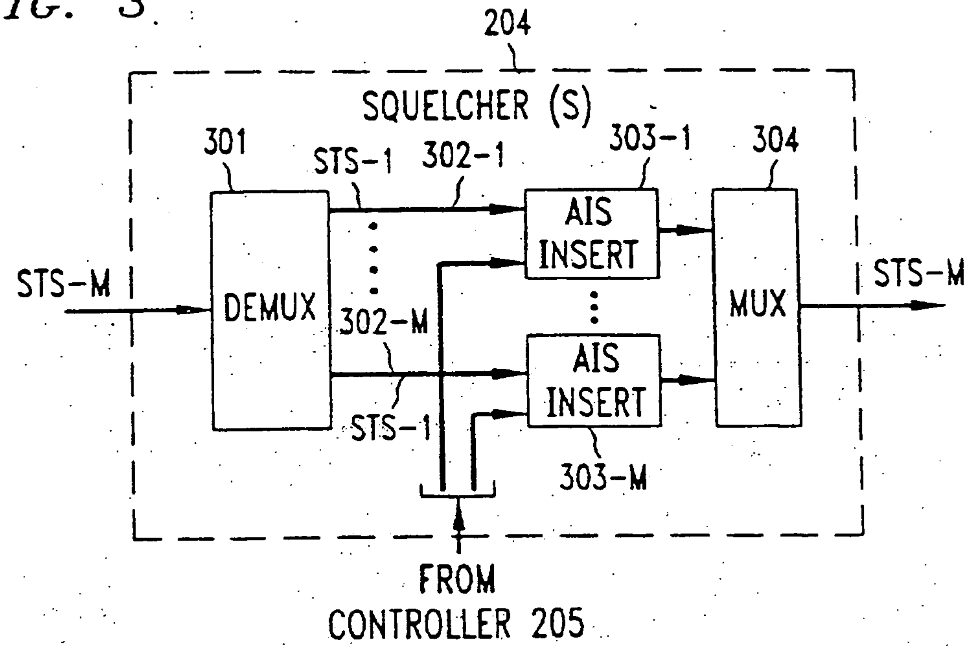

204
SQUELCHER (S)
301
STS-1
302-1
303-1
304
AIS INSERT
STS-M
DEMUX
302-M
MUX
STS-M
AIS INSERT
STS-1
303-M
FROM CONTROLLER 205

FIG. 4

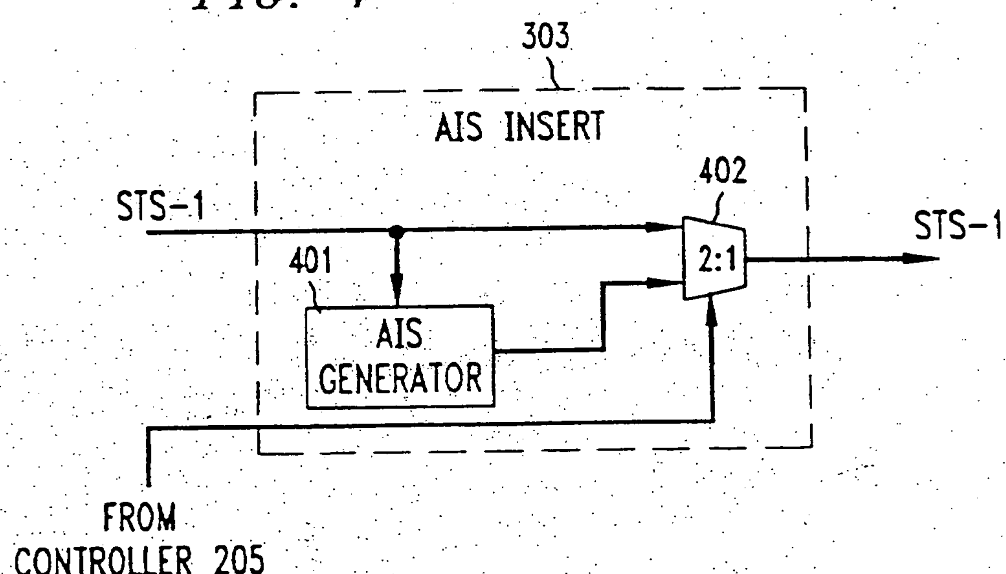

303
AIS INSERT
402
STS-1
401
2:1
STS-1
AIS GENERATOR
FROM CONTROLLER 205

FIG. 5

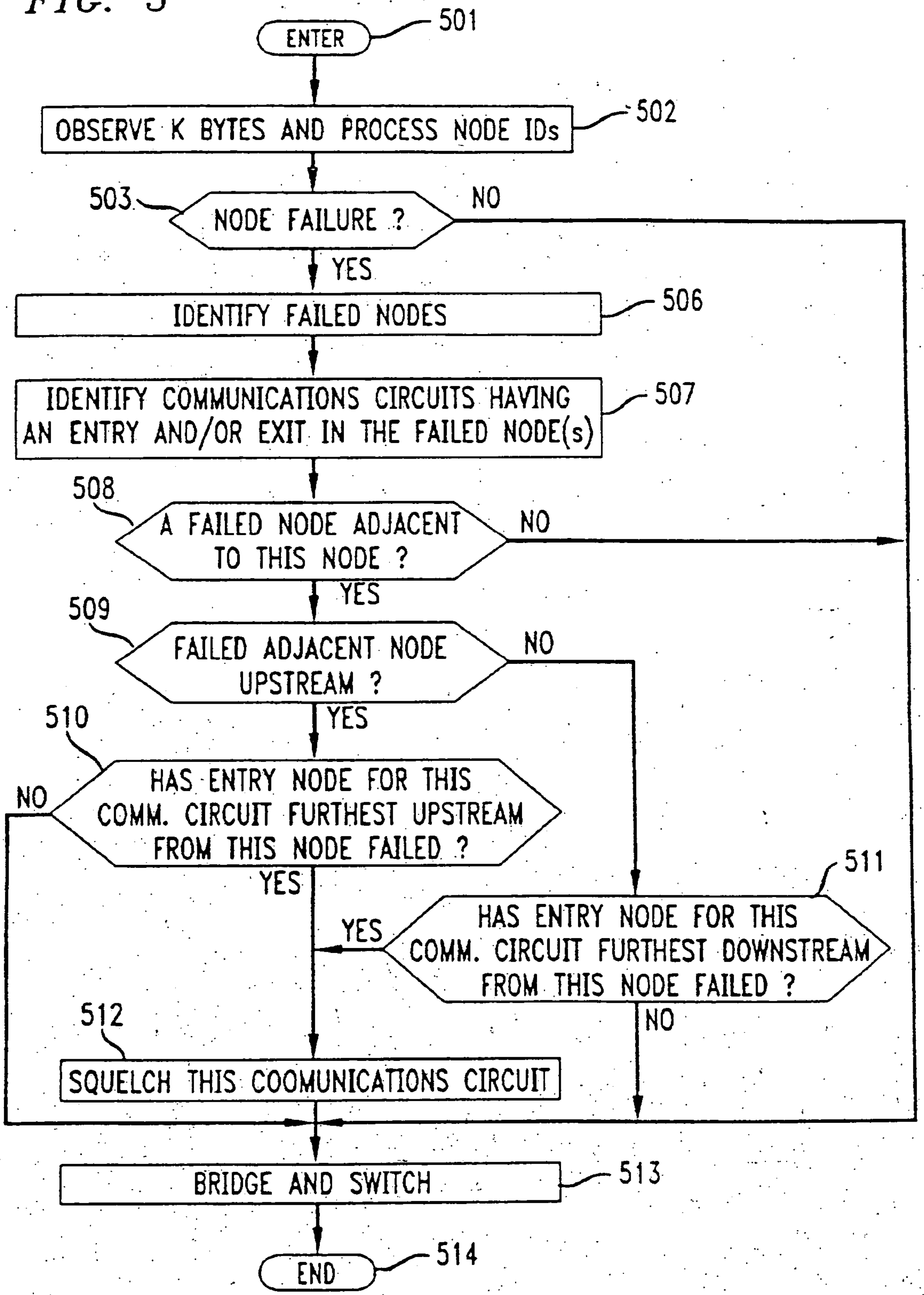

ENTER
501
OBSERVE K BYTES AND PROCESS NODE IDs
502
503
NODE FAILURE ?
NO
YES
IDENTIFY FAILED NODES
506
IDENTIFY COMMUNICATIONS CIRCUITS HAVING AN ENTRY AND/OR EXIT IN THE FAILED NODE(s)
507
508
A FAILED NODE ADJACENT TO THIS NODE ?
NO
YES
509
FAILED ADJACENT NODE UPSTREAM ?
NO
YES
510
HAS ENTRY NODE FOR THIS COMM. CIRCUIT FURTHEST UPSTREAM FROM THIS NODE FAILED ?
NO
YES
511
HAS ENTRY NODE FOR THIS COMM. CIRCUIT FURTHEST DOWNSTREAM FROM THIS NODE FAILED ?
YES
NO
512
SQUELCH THIS COOMUNICATIONS CIRCUIT
BRIDGE AND SWITCH
513
END
514

FIG. 6

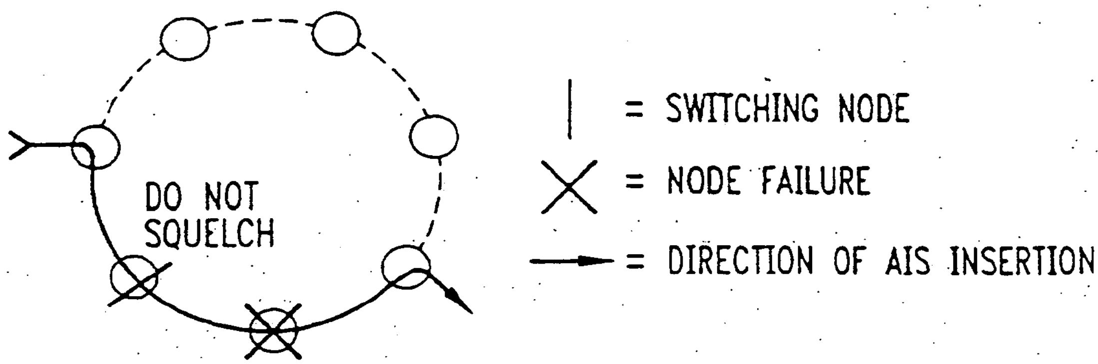


FIG. 7

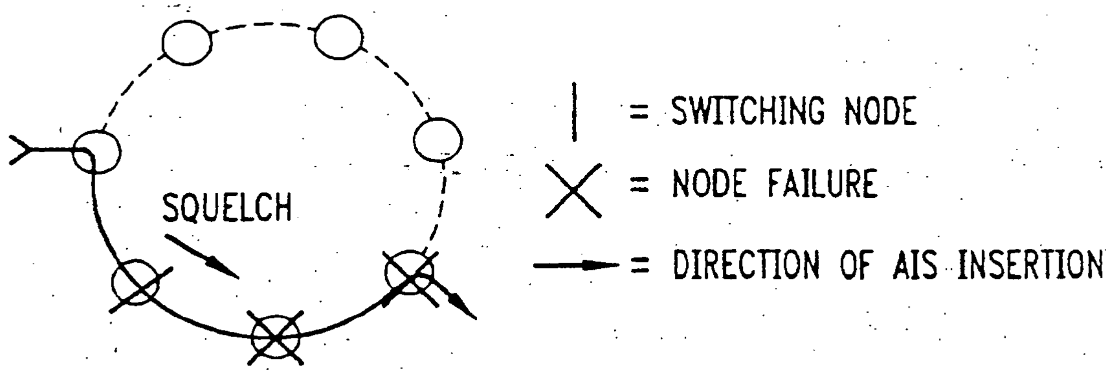


FIG. 8

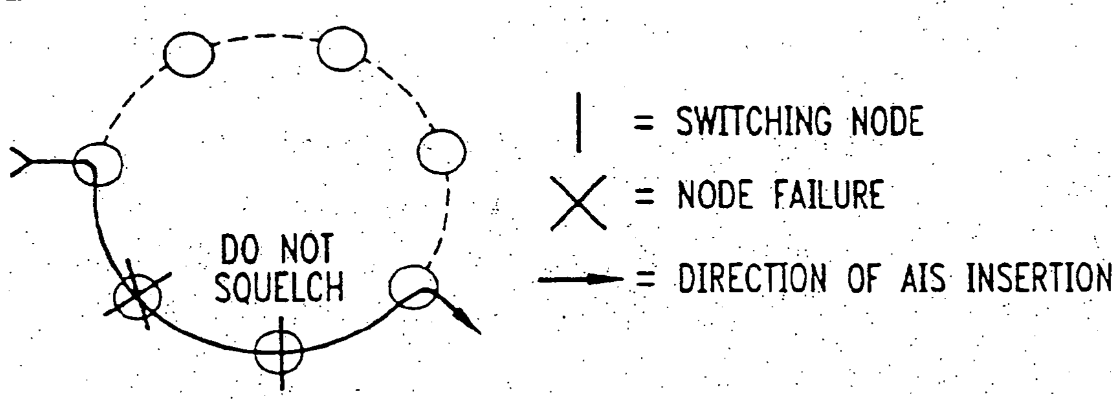


FIG. 9

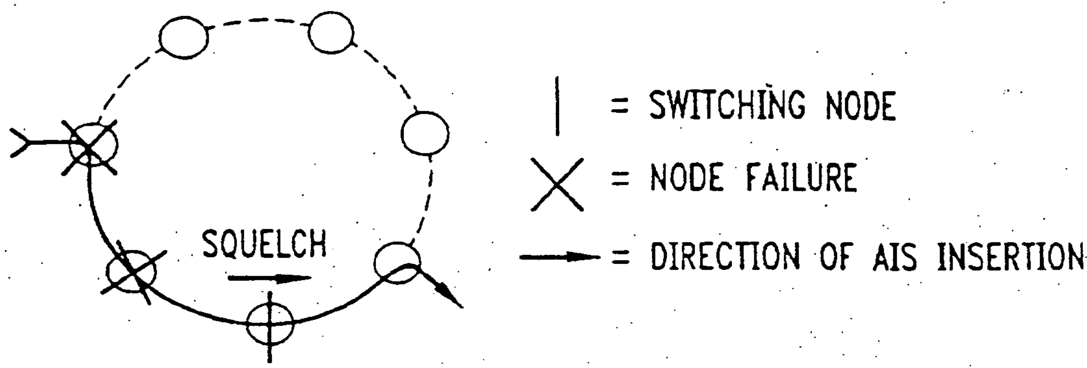


FIG. 10

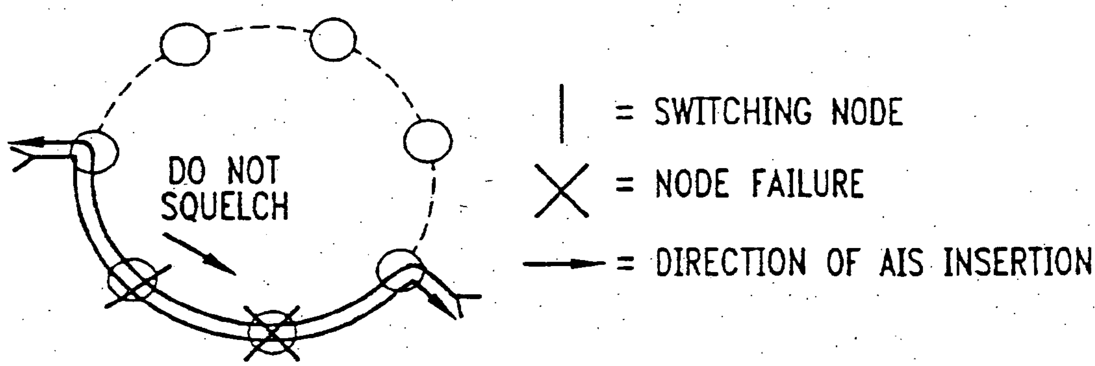


FIG. 11

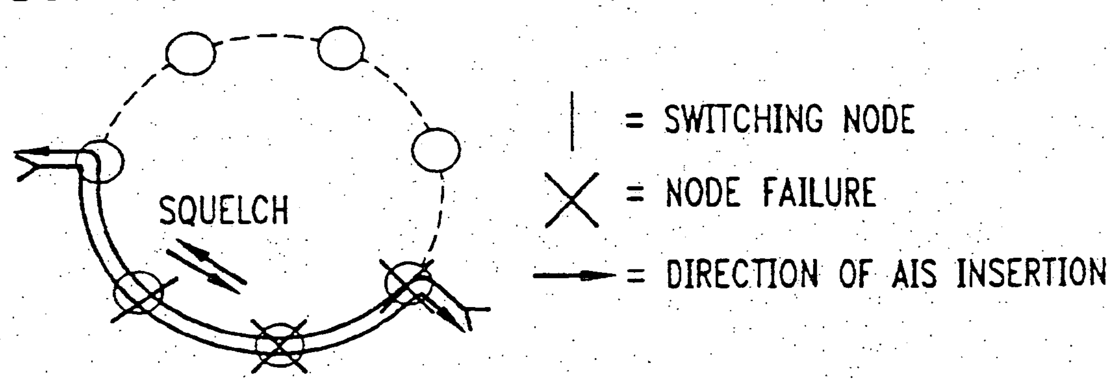


FIG. 12

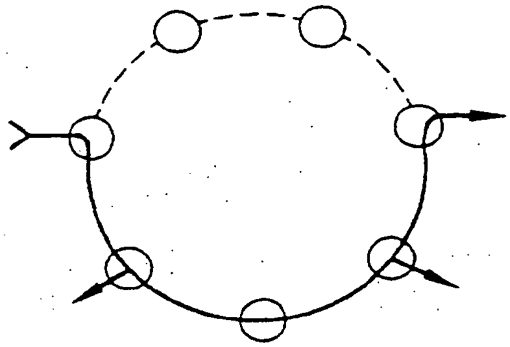


FIG. 13

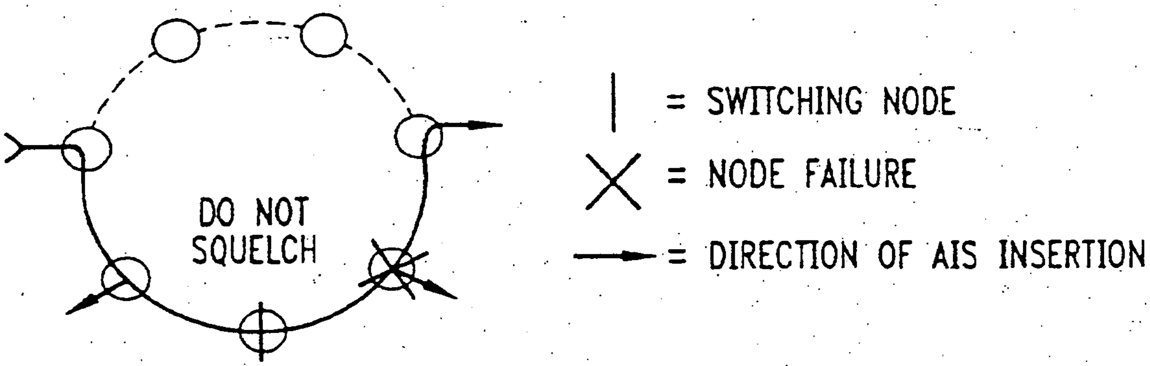


FIG. 14

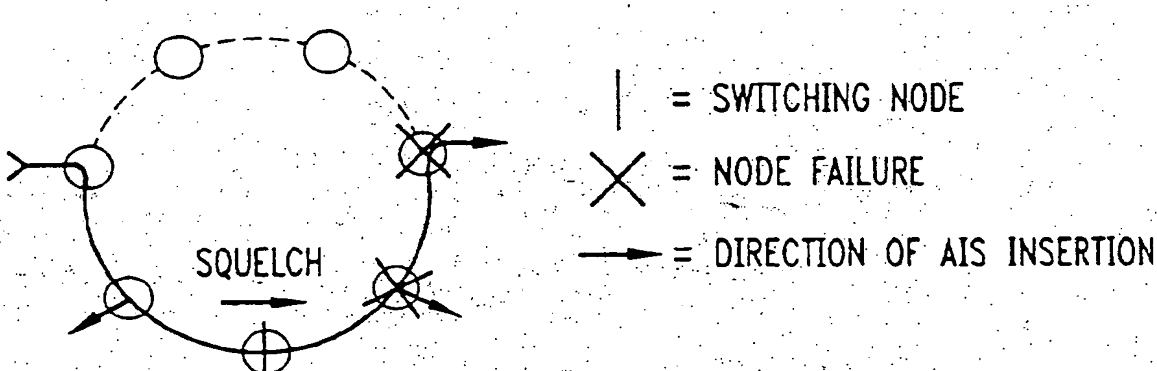


FIG. 15

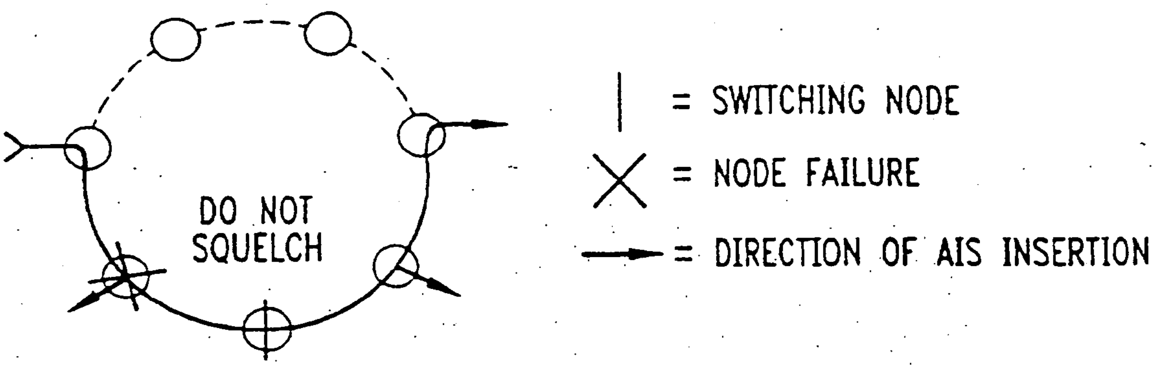


FIG. 16

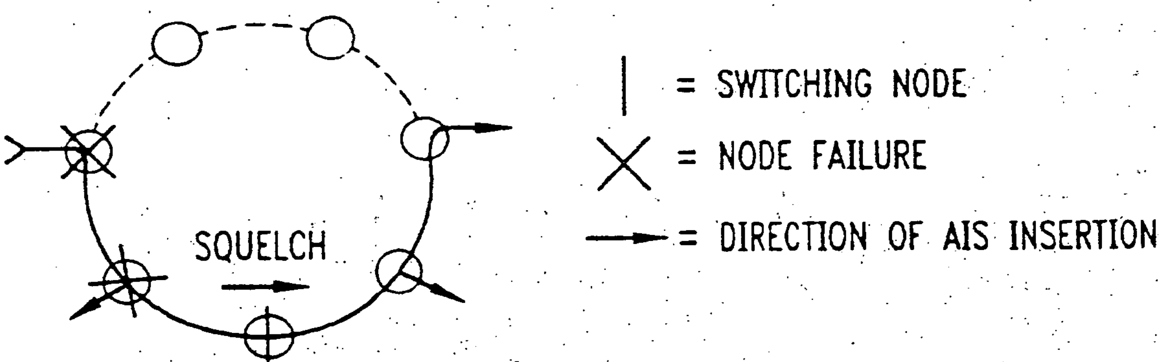


FIG. 17

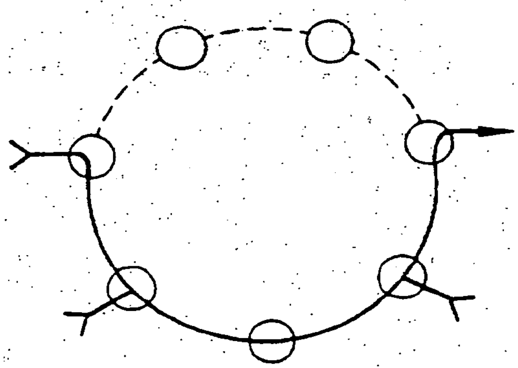


FIG. 18

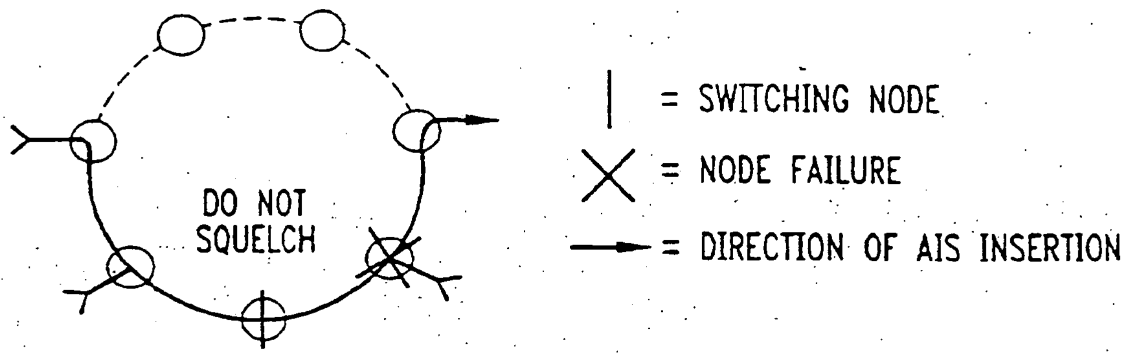


FIG. 19

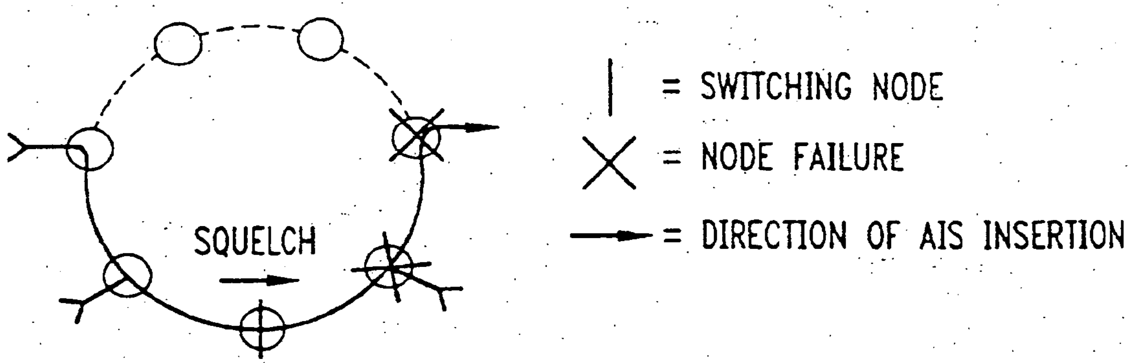


FIG. 20

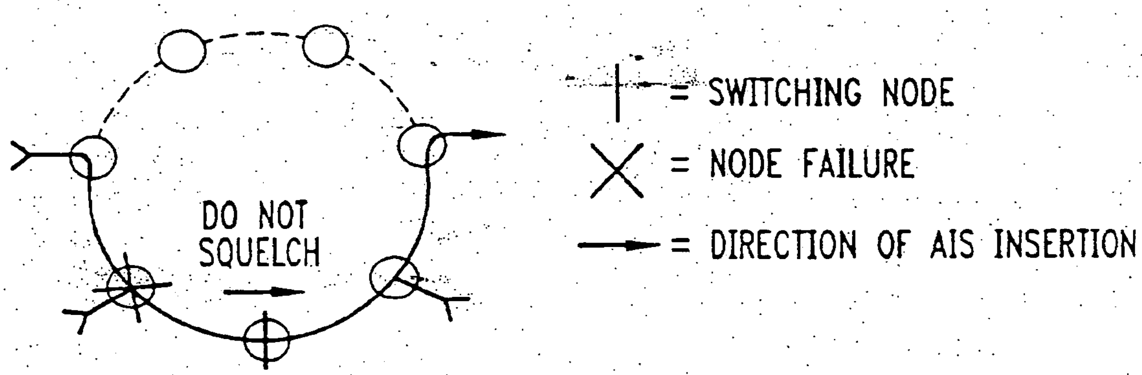


FIG. 21

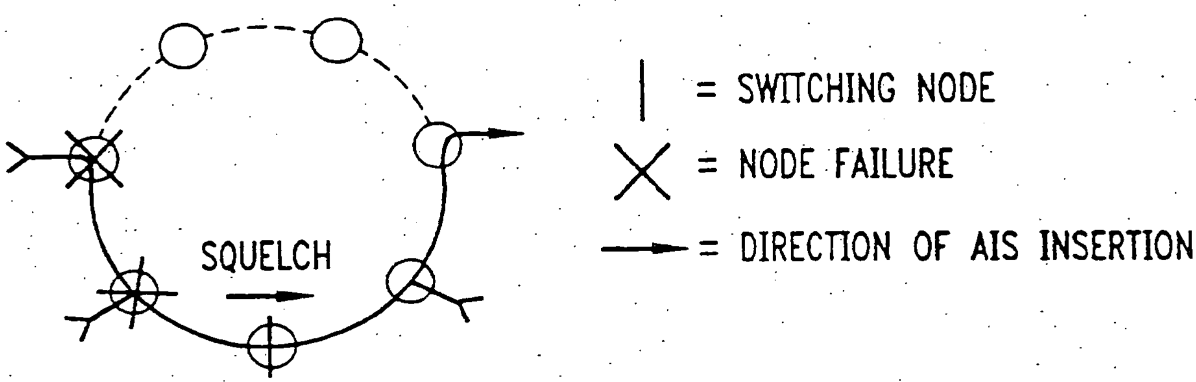
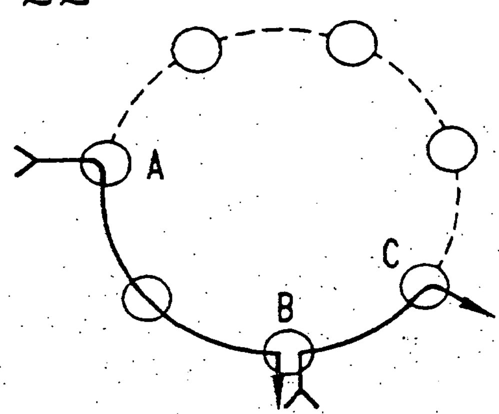

= SWITCHING NODE
= NODE FAILURE
= DIRECTION OF AIS INSERTION
SQUELCH

FIG. 22


A
B
C

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 708 542 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
13.01.1999 Bulletin 1999/02

(43) Date of publication A2:
24.04.1996 Bulletin 1996/17

(21) Application number: 95307185.9

(22) Date of filing: 11.10.1995

(51) Int Cl.[6]: H04J 3/08, H04L 12/437, H04Q 11/04

(84) Designated Contracting States:
DE FR GB IT NL SE

(30) Priority: 19.10.1994 US 325727

(71) Applicant: AT&T Corp.
New York, NY 10013-2412 (US)

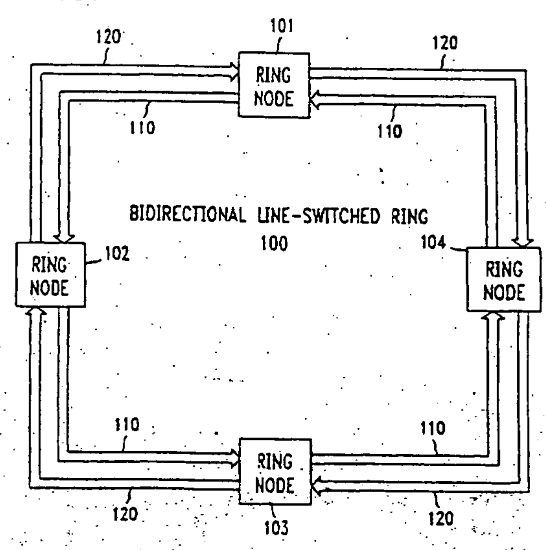
(72) Inventor: Kremer, Wilhelm
Andover, Massachusetts 01810 (US)

(74) Representative:
Buckley, Christopher Simon Thirsk et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green, Essex IG8 0TU (GB)

(54) Generalized deterministic squelching in a ring transmission system

(57) A method and apparatus for deterministically squelching communications circuits transported by a ring transmission system (100), including communications circuits with combinations of multiple drops, multiple sources and/or multiple broadcasts (in 101-104), is provided, in accordance with the invention, by a) identifying failed ring nodes (101-104) in the ring transmission system including locations of the failed ring nodes; b) identifying communications circuits active in the predetermined ring node; c) squelching a communications circuit active in the predetermined ring node in response to the identifications in steps a) and b) if a first ring node that is downstream from, and adjacent to, the predetermined ring node has failed, and an exit ring node for the communications circuit which is furthest downstream from the predetermined ring node has failed; and d) if no squelching is performed on the communications circuit in accordance with step c), then squelching the communications circuit active in the predetermined ring node if a second ring node that is upstream from, and adjacent to, the predetermined ring node has failed, and an entry ring node for the communications circuit which is furthest upstream from the predetermined ring node has failed.

FIG. 1



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 30 7185

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,A	CA 2 065 471 A (AMERICAN TELEPHONE & TELEGRAPH) 27 September 1993 * page 1, line 20 - line 33 * * page 3, line 34 - page 5, line 17 * * page 7, line 14 - line 25 * * page 9, line 14 - page 14, line 27 * ---	1-17	H04J3/08 H04L12/437 H04Q11/04
A	EP 0 590 872 A (AMERICAN TELEPHONE & TELEGRAPH) 6 April 1994 * column 1, line 38 - column 2, line 18 * * column 4, line 19 - column 7, line 52 * * column 9, line 55 - column 12, line 10 * -----	1-17	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H04J H04L H04Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 November 1998	Chauvet, C

CATEGORY OF CITED DOCUMENTS

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E : earlier patent document, but published on, or after the filing date
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